food and bioproducts processing 95 (2015) 27–37

Contents lists available at ScienceDirect

Food and Bioproducts Processing

journal homepage: www.elsevier.com/locate/fbp

Process optimization by response surface methodology and quality attributes of vacuum fried yellow fleshed sweetpotato (*Ipomoea batatas* L.) chips

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ARTICLE INFO

Article history:
Received 6 October 2014
Received in revised form 16 March 2015
Accepted 20 March 2015
Available online 28 March 2015

Keywords:
Vacuum frying
Sweetpotato chips
Optimization
Quality attributes
Carotenoid content
Oil content

ABSTRACT

A three-level Box–Behnken design was employed to study the effects and optimize the process parameters for vacuum frying of yellow fleshed sweetpotato (YFSP) slices for the production of healthy and nutritious fried snacks. The critical factors selected for the investigation were frying temperature (108–136 °C), vacuum pressure (4.91–19.91 cmHg) and frying time (3–9 min). The experimental results were fitted with a second-order polynomial equation by a multiple regression analysis and more than 80% of the variation could be predicted by the models. The optimal conditions for vacuum frying of YFSP slices determined using the numerical analysis were vacuum pressure of 10.12 cmHg at 108 °C for 9 min with desirability concept of 0.609. When optimized, vacuum fried samples were compared with atmospheric fried samples; the former absorbed about 60.42% less oil, and retained higher carotenoid (6.01 mg/g), with lower breaking force (15.9 N). Panellists preferred and accepted the optimized vacuum fried samples in all the sensory attributes investigated. The results suggested that vacuum frying of yellow fleshed sweetpotato chips is a better alternative to produce fried chips of acceptable and nutritional qualities.

1. Introduction

Sweetpotato (*Ipomoea batatas*) is a dicotyledonous plant with large, starchy, sweet-tasting, tuberous roots (Woolfe, 1992). Over 95% of the global sweetpotato (SP) crop is produced in developing countries, where it is the fifth most important food crop in terms of fresh weight. In 2004, approximately 129.5 Million MT was produced in more than 100 countries. It is high in carbohydrates and vitamin A and can produce more edible energy per hectare per day than wheat, rice or cassava. The yellow-orange flesh varieties also provide vitamins A and C. SP contain a wealth of orange-hued carotenoid pigments and in many countries throughout Africa, India and the Caribbean, it has been shown to be a highly effective way of providing school age children with sizable amounts of their daily vitamin A. In some studies, it had been shown to be a better source of bioavailable beta-carotene than green leafy vegetables (Bengtsson et al., 2010). Because it is available in many

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http://dx.doi.org/10.1016/j.fbp.2015.03.008

Nomenclature

ETDF	equivalent thermal driving force, N
FT	frying temperature, °C
Ft	frying time, minutes
VP	vacuum pressure, cmHg

countries on a virtual year-round basis, their ability to provide us with a key antioxidant like beta-carotene makes them a standout antioxidant food. Consequently, they are now being used in Africa to combat widespread vitamin A deficiency that results in blindness and even death for 250,000–500,000 African children a year (Low et al., 2007). The crop is widely cooked by deep fat frying in oil and consumed in form of French fries and chips (Farinu and Baik, 2007).

Vacuum frying is an excellent alternative to convectional frying since when frying below atmospheric pressure, significant advantages such as healthier and high quality products are obtained (Granda et al., 2004). The sample is heated under a negative pressure that lowers the boiling point of the frying oil and water in the sample. Absence of air during vacuum frying may inhibit lipid oxidation, and enzymatic browning of samples (Fan et al., 2005; Shyu et al., 2005). It is an efficient method of reducing the oil content of fried snacks, maintaining product nutritional quality, reduce oil deterioration and attain necessary degree of dehydration without excessive darkening or scorching of the product (Shyu et al., 2005).

As health issues become more important and consumers demand for healthier, low fat fried snacks with acceptable taste and texture is on the increase; most snack food industries continually search for products and process that will please consumers and address nutritional concerns. Even though frying is an old manufacturing process for food product worldwide, most of the research found in the literature is related to atmospheric frying. Several pre-treatment methods have been used to reduce the oil content of fried fruits and vegetables including blanching, pre-fry drying and osmotic dehydration (Krokida et al., 2001; Sobukola et al., 2008, 2010; Kim and Moreira, 2013). However, none of these methods have been able to present products that match the quality attributes expected by the consumers. In the same vein, a number of researchers have investigated vacuum frying conditions and quality of snack products in recent years. These include vacuum fried potato chips (Garayo and Moreira, 2002), apple chips and carrot chips (Dueik et al., 2010), banana slices (Yamsaengsung et al., 2011), banana chips (Yamsaengsung and Ngamnuch, 2005), apples (Shyu and Hwang, 2001), other types of fruits and vegetables (Da Silva and Moreira, 2008), and recently fabricated snacks (Sobukola et al., 2013a,b). However, vacuum frying of yellow fleshed sweetpotato slices has not been reported in details to explore the relationship between process variables and characteristics of the vacuum fried chips. A study such as this is very important in product and process development considering the popularity of fried snacks in terms of quality and nutrition. Hence, the aim of this study was to investigate the optimum processing conditions and the effects of the vacuum frying process variables on the quality characteristics of vacuum fried sweetpotato chips using RSM. In addition, regression equations to predict the quality attributes of the vacuum fried chips as a function of the process variables were also established. A comparison between of the optimized vacuum fried samples and atmospheric fried samples was undertaken while sensory analysis was also used to determine the preference and overall acceptability among the samples.

2. Materials and methods

2.1. *Experimental materials and preparation*

Yellow fleshed SP (440216) was procured from a local market in Abeokuta, South West, Nigeria. Prior to each set of experiments, SP tubers of known weight were selected from the lot. Refined bleached deodourized vegetable oil commonly used for frying in the study area was purchased from the local market in Abeokuta. The fresh tubers were sorted and graded according to uniformity of size and those with defect or disease were discarded. After sorting, the tubers were then washed in clean water prior to peeling using very sharp stainless steel knives. Peeled tubers were then cut into slices of about 2 ± 0.35 mm and diameter of about 30 ± 0.07 mm. Surface starch from the sweetpotato slices were washed off by placing the slices in a water bath at 30 °C while excess surface water was removed by placing the slices between moistened towel.

2.2. *Vacuum frying set up*

A laboratory size vacuum fryer equipped with a centrifuge (model no: VF 8.0, SitusMESIN, Indonesia) was used for the vacuum frying experiments as indicated in Table 1. The vacuum vessel was set at the desired frying temperature for about 30 min before the start of frying. Once the oil temperature reached the target value, eight SP slices were placed into the frying basket, the lid closed, and the vessel evacuated untill the desired vacuum level is reached. At this moment, the basket was lowered into the oil and frying began. Once the slices has been fried for the required frying time, the basket was lifted from the oil and the vacuum broken. The lid of the vessel was opened and the vacuum fried SP chips were removed from the basket, allowed to cool to room temperature on paper towel prior to packing in polyethylene bags for further analysis.

2.3. *Sample analyses*

Standard analytical procedures based on AOAC (1995) was used to determine moisture and oil contents of the fried samples and reported as dry basis.

2.3.1. *Determination of color parameters*

2.3.1.1. *Image capture*. The method used by Mariscal and Bouchon (2008) was adopted using a colored digital camera (model Nikon COOLPIX L_{21}, Japan). The digital camera was mounted on a stand inside a box impervious to light with internal black surfaces. Four flourescent lamps were placed inside the box to illuminate the interior area of the box and placed

Table 1 – The coded values for the independent variables.

Variable	−1	0	+1
Temperature (0 °C)	108	122	136
Pressure (cmHg)	4.91	12.41	19.9
Time (min)	3	6	9